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THE ECOLOGICAL SIGNIFICANCE OF THE EAGLE CREEK FLORA OF THE COLUMBIA RIVER GORGE

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INTRODUCTION

During the seasons of 1916 and 1917 considerable collections of fossil plant material were made by the writer in the gorge of the Columbia River, in Oregon and Washington. It has been planned to present a complete report on this material, including a description of new forms, a discussion of the age of the flora, and a consideration of its ecological significance. In view of the possible interruption of this larger task a discussion of the ecological significance of the flora is presented in advance of the fuller report.

Acknowledgment is made to Dr. J H. Bretz, of the University of Chicago, who first directed the writer's attention to this field, and who is responsible for the discovery of one of the most important plant-bearing deposits. I am indebted also to Dr. F. H. Knowlton

for valuable advice and assistance in determining species, and to Dr. H. C. Cowles, of the University of Chicago, for his direction in the interpretation of the ecological data. The work during the season of 1917 was carried on with the aid of a grant from the Research Fund of the American Association for the Advancement of Science, to which organization sincere acknowledgment is due.

GEOGRAPHIC LOCATION AND TOPOGRAPHIC FEATURES OF THE COLUMBIA GORGE

The gorge of the Columbia River is that portion of its valley in the Cascade Range. Its general features are shown in the Mt. Hood sheet of the United States Geological Survey, where the Columbia River forms the boundary between Oregon and Washington. The river has exposed here a section which has a maximum thickness of over 4,000 feet. The basal Eagle Creek formation is displayed at the axis of the range, giving the most complete section just west of the boundary between Multnomah and Hood River counties. The total length of the gorge from Troutdale, Oregon, on the west to The Dalles, Oregon, on the east is about 70 miles. Its width averages about one mile.

The walls of the gorge rise steeply, especially on the Oregon side, where cliffs of basalt rise more than 2,000 feet almost vertically. A number of peaks, some of them representing volcanic cones, lie a short distance back from the edge of the walls. Larch Mountain, 4,045 feet, and Mt. Defiance, 4,960 feet, are conspicuous examples. Numerous small tributary streams flow into the Columbia from each side through canyons which are much shallower than that of the master-stream. As a result each has at or near its mouth a falls or series of falls, the highest being Multnomah Falls, 620 feet high, at the mouth of Multnomah Creek. The sections exposed in the lower stretches of these tributaries add much to our knowledge of the stratigraphy and fossil content of the rocks.

The western two-thirds of the gorge is occupied by the luxuriant forest of Douglas spruce so characteristic of the Pacific coast. Much of the geologic record is hidden by the density of this forest and its undergrowth. The best accessible sections are found where the building of roads and trails has temporarily destroyed the

vegetation cover. Conditions become progressively more arid toward the east, with only a sparse occurrence of pines and oaks at The Dalles.

GEOLOGIC RELATIONS OF THE EAGLE CREEK FORMATION

A recent study of the geology of the Columbia River Gorge by Drs. I. A. Williams and J H. Bretz under the auspices of the Oregon Bureau of Mines has given us a rather complete knowledge of the general geology of this little-known region.[1] As far back as 1873 LeConte recorded the presence of fossil leaf impressions in the volcanic conglomerate at the base of the basalt series.[2] In 1895 Diller secured a small collection of leaves near the mouth of Moffatt Creek which has been described by Knowlton,[3] and four years later Gilbert made a larger collection from a talus block near Cascade Locks, a collection which has never been described. The collections which are the basis of this paper are, however, the first which are sufficiently complete to give any conclusive evidence regarding the age of the Eagle Creek formation.

There are but few cases of such an illuminating record of the history of a mountain range as has been furnished by the Columbia River in its path across the Cascades. Following is the generalized section exposed by the Columbia: gravels and river terraces of recent origin; Herman Creek lava—andesitic basalt; Satsop formation—stream gravels and volcanic ash; Columbia River lava—successive flows of basalt; Eagle Creek formation—volcanic conglomerate, ash, and tuff.

The Eagle Creek formation.—The Eagle Creek formation is exposed along the bottom of the gorge from Warrendale to Viento on the Oregon side with a corresponding distribution on the north side of the river. It is the oldest formation recognized in the region, and is brought to the surface in the axis of the great north-south anticline which is the backbone of this portion of the range. The thickness of the exposed part of the formation varies from 2,700

[1] Ira A. Williams, *Bull. of the Ore. Bureau of Mines and Geol.*, Vol. II, No. 3, 1916; J H. Bretz, unpublished manuscript.

[2] J. LeConte, *Am. Jour. Sci.*, 3d Series, VII, 167–80.

[3] F. H. Knowlton, *Twentieth Ann. Rept. U.S. Geol. Surv.*, pp. 37–64.

feet at Red Bluffs on the Washington side to 500 feet on the Oregon at Bonneville, a condition which appears to be due in part at least to the southward plunge of the fold.

The formation as exposed on Table Mountain and Red Bluffs comprises a series of beds of tuff, ash, and volcanic conglomerate, the conglomerate being most conspicuous near the top. In several of the talus masses of the conglomerate poorly preserved leaf impressions are found, and in both the conglomerate and the tuff silicified wood is common. To the west of Red Bluffs cliffs of conglomerate are conspicuous, and from them have slumped the great masses of rock which have dammed the Columbia River, resulting in its cascades. The base of the formation is reached neither on the Washington nor on the Oregon side.

On the Oregon side the maximum section exposed, 500 feet thick near Bonneville, is a volcanic conglomerate, in most places highly indurated. All the bowlders are of porphyritic basalt, some of them reaching a diameter of 15 feet and averaging from one to three feet in the coarser phases of the formation. The matrix is a fine to coarse volcanic sand. Numerous pockets and lenses of shale and sandstone are a characteristic feature. These are of slight extent both vertically and horizontally, and in many cases contain more or less well-preserved leaf impressions. Silicified logs and carbonized stems and fragments are of common occurrence, representing driftwood deposited with the sediments.

The frequence of volcanic activity during the deposition of the sediments is indicated by the seams of volcanic ash which are seen to overlie some of the soil layers representing old surfaces. A quarter of a mile east of Bonneville occurs what is most probably a contemporary extrusion of basalt, and on Greenleaf Creek the sedimentaries are intruded by basalt. In these situations and elsewhere locally the beds have been contorted and shattered, with the development of slickensided surfaces and contact metamorphism.

The upper surface of the Eagle Creek formation, overlain by basalt flows, is markedly irregular, as first noted by LeConte in the canyon of Tanner Creek.[1] Evidences of intraformational unconformities are numerous and will be discussed below.

[1] *Op. cit.*

Collections of leaf impressions were made in eighteen localities, ranging from the mouth of Moffatt Creek on the Oregon side of the gorge to the foot of the cliffs at Red Bluffs in Washington, six miles distant. These collections, while made up of rather fragmentary material on the whole, include remarkably well-preserved leaves where the matrix is a fine clay. In most situations the leaves were secured just above a layer of carbonaceous shale which represents the old soil line, in the fine sandy or shaley material laid down upon the old surface.

The following description of a locality on the Columbia River Highway shows the typical occurrence of the fossil plants: 850 feet

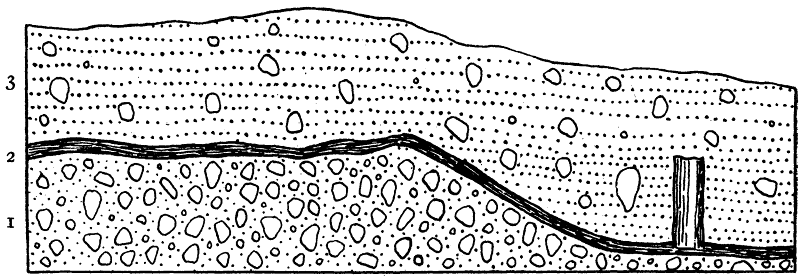

FIG. 1.—Section of the Eagle Creek formation 850 feet west of the Tanner Creek bridge on the Columbia River Highway, showing relations of the soil line and the upright tree.

west of the Tanner Creek bridge on the Columbia River Highway, a bed of cobble conglomerate 20 to 25 feet in thickness is overlain by a carbonaceous seam containing leaves. The general relations are shown by Fig. 1. Here bed 1 is a layer of coarse conglomerate which is overlain by bed 2, a seam of carbonaceous sandy shale from 8 inches to 3 feet in thickness. Overlying bed 2 and inclosing the fossil tree which is rooted in the shale is bed 3, comprising 15 feet of sandstone containing numerous bowlders.

The upper surface of 1 is suggestive of an erosion surface on which several feet of soil 2 accumulated. The upright tree appears to have been growing in a valley cut in 1 during the time of the soil accumulation, and about its roots numerous leaves have been buried and fossilized.[1] The lack of another slope makes the

[1] A microscopical examination of this fossil wood has not yet been made to determine its taxonomic relations.

assumption of a valley uncertain, but in any case the sloping soil line establishes the fact that this old land surface had considerable relief at the time 3 was deposited on it.

The age of the Eagle Creek formation has been imperfectly known; due to the small amount of fossil material previously secured from it. On the basis of these more extensive collections it will be possible to fix the age with reasonable certainty. At present the age may be referred tentatively to Upper Eocene on

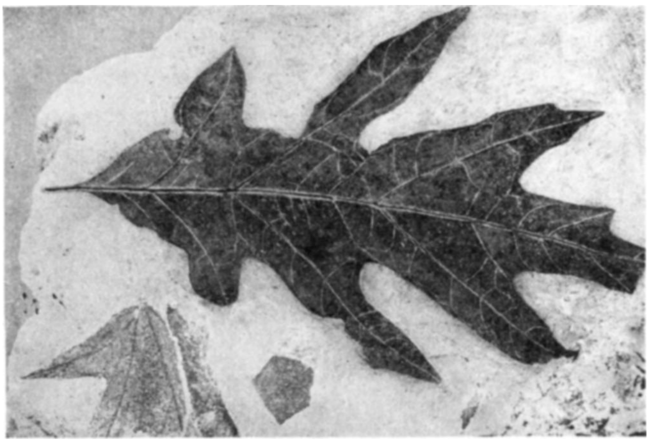

FIG. 2.—*Quercus pseudo-lyrata.* One-half natural size

the basis of close resemblances of the flora to that of the Upper Clarno beds of the John Day Basin and related formations in Idaho and California.

THE ECOLOGICAL COMPOSITION OF THE FLORA

It is not the purpose of this paper to describe the composition of the Eagle Creek flora from the taxonomic standpoint. It will be sufficient to note that of some 80 species represented, 75 are angiosperms, of which but 2 are monocotyledons. Following is a provisional list of the genera, with the number of species included in each: *Ginkgo* 1, *Pinus* 1, *Picea* 1, *Smilax* 1, *Cyperacites* 2, *Populus* 3, *Salix* 3, *Hicoria* 2, *Juglans* 1, *Alnus* 1, *Carpinus* 1, *Corylus* 1, *Castanea* 1, *Quercus* 12, *Ulmus* 2, *Planera* 2, *Magnolia* 1,

Laurus 2, *Platanus* 2, *Liquidambar* 3, *Crataegus* 1, *Sterculea* 1, *Rhus* 1, *Ilex* 1, *Acer* 3, and *Fraxinus* 1.

Considering the ecological composition of the flora, the outstanding feature is the presence in it of leaves which represent two distinct ecological types, one xerophytic and the other mesophytic. The former includes several species of oaks, notably *Quercus pseudo-lyrata* (Fig. 2), which is the most abundant species in the flora. The latter comprises most of the remainder of the flora, including a large number of genera and species, of which *Acer bendirei* is represented by the largest number of specimens.

FIG. 3.—*Acer bendirei*. One-half natural size.

Quercus pseudo-lyrata, the most abundant species, is found in twelve of eighteen localities furnishing leaves. Clearly the conditions under which it lived may be said to be widespread. Its leaves have the thickness and coarse epidermis which constitute the morphological expression of a xerophyte. Its modern representatives, *Q. velutina*, *Q. muhlenbergii*, and *Q. marylandica*, have their typical range in xerophytic habitats. It seems entirely probable that *Q. pseudo-lyrata* occupied a similar habitat, an exposed situation with a small amount of moisture.

Associated with this presumably xerophytic species, commonly in the same slab and almost invariably in the same locality, is *Acer bendirei* (Fig. 3), a maple closely related to *A. macrophyllum*, which is an abundant member of the flora now living in the gorge. Even were it not well known that maples are almost exclusively found in well-watered habitats, the mesophytic character of *Acer bendirei* could be ascertained from the thin texture and large size of the fossil leaves. Occurring in fourteen out of eighteen localities it is an abundant species and one which shows moisture requirements widely different from those of *Quercus pseudo-lyrata*.

There is little reason to doubt that these two ecological types represent two distinct habitats from which leaves have become intermingled and fossilized. The abundance of individual oak leaves is adequate evidence that they have not come from scattered relicts of an earlier succession which has been supplanted by one more mesophytic. On the assumption that the xerophytic leaves are xeromorphs and owe their structure to a physiologically dry habitat such as a bog, a twofold habitat would still be required, for such xeromorphic forms would not be included in the same association with typical mesophytes like *Acer*, *Ulmus*, and *Platanus*. Further, the typical xeromorphic leaf is entire-margined, while *Quercus pseudo-lyrata* has conspicuous lobes and sinuses. On the basis then of two habitats contributing leaves, we may consider the general type of topography required by the plant evidence.

In many parts of the United States today the uplands are occupied by a xerophytic oak association due to the exposure of such a habitat to the sun and the wind, and the consequent high rate of evaporation. Where such an upland is dissected by valleys, especially by those with rather deep and narrow dimensions, these more protected situations may furnish conditions favorable for the development of a typical mesophytic flora. We may have, then, as a common occurrence, a xerophytic upland association with mesophytic tracts along the streams. Leaves from the upland trees are transported widely, due to exposure to winds, and may be carried down into the valleys and mixed with those of the mesophytes growing there. Such situations are so common today that there is little danger in assuming that they were common during the Eagle Creek epoch, though the geological evidence of such topography should be forthcoming if such were the case. On the basis of the plants, however, it is reasonable to assume the existence of this upland habitat, supporting an oak forest, and occasional valleys occupied by mesophytic maples, elms, and other species.

The mixture of the xerophytic and mesophytic types of leaves may thus be explained on the basis that the former were brought in from above and mixed with the mesophytes in the valley deposits. Aside from the exposed situation of the uplands, which would

favor the wide scattering of the leaves which fell upon it, there is the added feature that the thick xerophytic leaves alone would be strong enough to undergo transportation without being destroyed. Surely we must assume that the perfect specimens of maple, sycamore, and other broad thin leaves were not transported far from the spot where they first fell. Further, the large number of mesophytic species associated with the dominant maple and elm leaves indicates that the deposits containing them were laid down in the valley where they grew.

The evidence of the plant fossils thus may be explained on the basis of a twofold habitat such as would be furnished by an upland region traversed by valleys. Whether or not this hypothesis is supported by the geological evidence may be determined by a consideration of the physical conditions which existed during the Eagle Creek epoch.

PHYSICAL CONDITIONS DURING THE EAGLE CREEK EPOCH

The Eagle Creek formation is made up entirely of volcanic materials. In the lower part, as exposed at Red Bluffs, beds of tuff and ash are most conspicuous; above, the activity of streams is evidenced by the predominance of conglomerate. Thus it is clear that early in the epoch vulcanism was the dominant process but that toward the close the streams were able to carry and assort the volcanic material as fast as it was ejected, as well as erode the lava flows bordering the craters. This sedimentary phase is the only one represented on the Oregon side of the gorge and is the source of practically all of the fossil plants.

There are several conspicuous features, applying especially to the conglomeratic phase, which require analysis. In the first place there is a predominance of coarse material—rounded bowlders ranging up to 15 feet in diameter and averaging from 1 to 3 feet. The textural range is high in any outcrop, large bowlders mingled with small, all bound together by a matrix which varies from coarse gravel to fine mud, but is commonly sandy in texture. The abundance of large bowlders and the almost entire lack of assortment point to the deposition of these sediments by streams which had high velocity.

In the second place the stratification where present is of the lens and pocket type rather than in horizontal layers. This applies to coarse as well as fine materials, but is especially conspicuous in the case of the latter. Nearly all of the sandy and shaley phases occur in the form of lenses or pockets having a horizontal distribution of a few tens of feet and a thickness, with few exceptions, of not more than 15 to 20 feet. This is suggestive of fluctuating conditions of deposition, due either to a variation in the kind of materials available for transportation by the streams, to a variation in the volume of the streams, or to a wandering of the streams over the depositing portions of their courses.

Both of these features suggest that the sedimentation was of the bajada type, like that on the flanks of the Sierras.[1] If the Eagle Creek conglomerates were laid down as alluvial fan deposits, it is clear from their thickness that they were deposited on the flanks of a range of considerable height. This brings to consideration a third feature, that of the variation of thickness in the area. At no place is the base of the formation reached, but the observed thickness at Red Bluffs is 2,700 feet, while south of the river its exposed part is little more than 500 feet thick. This variation may be explained in two ways: first, that it is due to the southward plunge of the Cascade anticline, which would carry the top of the formation down to within 500 feet of river level (assuming a dip of about 10°); and, second, that it is related to the position of the high land which was the source of the sediments, the deposits on the immediate flanks being thickest, with a thinning outward as the distance from the source increased. Assuming that the Eagle Creek conglomerates were laid down on the flanks of an east-west range, as shown by Fig. 4, there should be other evidences of the proximity of the thicker section to the flanks of the range. It is probable that this range contained the vents from which the pyroclastics were ejected. We should therefore expect to find ash and tuff more conspicuous in that portion of the bajada nearest the range. At Red Bluffs, as has been stated, ash and tuff in alternating layers comprise most of the visible portion of the Eagle Creek formation, except near the top, where conglomerate is more

[1] A. C. Trowbridge, *Jour. Geol.*, XIX, 707–47.

conspicuous. On the Oregon side, farther away from the supposed range, the amount of pyroclastic material is relatively inconspicuous, as might be expected at a distance of 6 to 8 miles from the range.

It may be suggested that the 500-foot section of conglomerate on the Oregon side of the gorge represents the upper conglomeratic portion of the Red Bluffs section, and that the ashy and tuffaceous lower portion lies below. Surely the southward dip of the overlying basalt makes this explanation of the variation in thickness plausible. On the other hand, it appears reasonable to suppose that the 500 feet exposed on the Oregon side represents more than

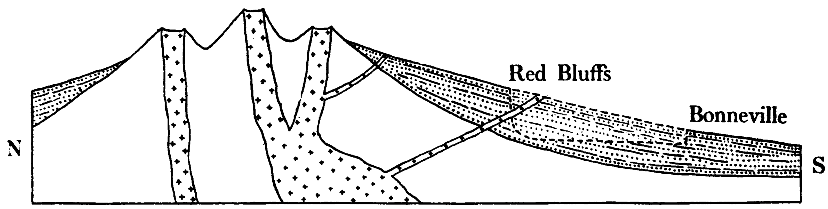

FIG. 4.—Showing the possible relations of the Eagle Creek formation on the flanks of a volcanic peak or range. The dashed line indicates the present position of the Gorge of the Columbia River in cross section.

the upper 500 feet of the Red Bluffs section. There are more intrusions in the latter, as might be expected at a point nearer the mountain range. And the paucity of plant remains in the conglomerates of Red Bluffs also has significance when it is realized that the proximity to volcanoes would probably be unsuitable for the growth of vegetation. It is of course possible that were the upper part of the Eagle Creek section readily accessible for study, plant-bearing lenses might be found in abundance there; but in all of the talus material examined at the foot of the cliffs only two masses contained leaf impressions, and these but few. The variation in thickness of the formation from north to south may then be due to a greater or less extent to the distance from the range constituting the source of the sediments.

In summary, the lithological characters of the Eagle Creek formation—its coarseness, lack of assortment, and lens and pocket stratification—point to the origin of the conglomeratic layers as a

bajada deposit on the flanks of a mountain range lying to the north, a range whose volcanoes threw out the great volume of pyroclastic material, and which later were perhaps the sources of the basalt flows. The variations in thickness from north to south are in accord with this geographic relation, for the formation appears to thin toward the south.

We may outline the physical history of the Eagle Creek formation as follows: To the north of the gorge, an east-west range of mountains contained volcanoes which were active throughout the epoch, though probably less active toward its close. Large amounts of ash and tuff were thrown out, covering the flanks of this range to a depth of more than 2,000 feet. During intervals of volcanic inactivity streams assorted this material, producing the beds of volcanic conglomerate. Toward the close of the epoch streams assumed dominance and transported large amounts of volcanic débris out from the axis of the range, depositing it as far away as the present south side of the gorge but in progressively lesser amounts. Thin layers of ash in the sections on the south side indicate that a small amount of pyroclastic material was carried there directly from the vents. The dominance of clastic sediments indicates, however, the relatively greater importance of stream deposition here, and the presence of conditions suitable for the development of plant life.

Some idea of the topographic relations of such a bajada deposit on the flanks of a high range may be gained from the description of similar deposits of the Sierras.[1] Here the alluvial plain is traversed by numerous streams flowing out at right angles from the range, streams which on losing their gradient drop their loads of coarse débris. This piles up until the deposit is considerably higher than the areas on either side, whereupon the streams are shifted laterally into the lower areas and deposition is continued there. For the purposes of this discussion it is sufficient to note that the surface of the bajada in the Sierras is characterized by numerous rather steep-sided ridges which result from stream deposition, and that most of the vegetation is found in the valley-shaped lowlands between.

[1] A. C. Trowbridge, *op. cit.*

We may now turn to the plant record to see how the biological evidence corresponds with the geological. It will be recalled that there are two distinct ecological types represented in the flora, the one composed of fewer species but including the larger number of individual leaves, indicating an exposed habitat; the other composed of many species, indicating a protected habitat. Clearly the xerophytic association would have found its place on the ridges, the mesophytic association in the depressions such as are furnished by the bajada topography. Leaves from the oaks on the ridges might easily be blown or washed into the depressions below, there to be mixed and buried with the leaves of the mesophytic maples and elms growing along the streams. The bajada topography fits well with the ecological requirements of two habitats, one exposed and xerophytic, the other protected and mesophytic.

However well these ecological requirements are fulfilled by the bajada topography, there should be some actual record of the latter if it existed during the Eagle Creek epoch. During the first season's work no such evidence was discovered. The requirements of the plants were unsatisfied until a second visit to the gorge, during which several situations were found where the topography developed during the epoch showed distinct relief. Along the Columbia River Highway cut west of the Tanner Creek bridge, two places were noted where a soil line slopes sharply into a depression. In one of these (see Fig. 1) the soil line slopes down at an angle of 22° and the depression below contains the upright stump of a large tree. Similar situations on Moffatt and Eagle creeks were observed. In the latter the material deposited over the leaf-bearing bed is clearly a valley fill, as shown by the horizontal bedding of the gravelly layers in the sandstone. Further, as previously noted, the upper surface of the formation has marked relief. Clearly the old surfaces within and at the top of the formation show that there were ridges and depressions such as the evidence of the plants demands and such as would have been present in a bajada deposit.

A consideration of the climatic conditions indicated by the plants is next in order. The numerical predominance of the xerophytic form, *Quercus pseudo-lyrata*, and its occurrence in nearly all the deposits where large collections were made indicate

that the upland conditions were such as to support an oak forest. Today the uplands, in the western part of the gorge at least, are occupied by the more mesophytic Douglas spruce (*Pseudo-tsuga*). Comparing the upland plant associations of the Eagle Creek epoch and the present, we are justified in concluding that the climate was more arid then than it is now. Looking to the mesophytic valley association of the Eagle Creek flora, the presence in it of such moisture-requiring forms as *Acer bendirei*, *Ulmus speciosa*, and others indicates that in the depressions the air was moist. This moisture was no doubt contributed in large part by the streams occupying the valleys, but the very presence of so mesophytic an association indicates that even semiaridity did not exist anywhere in the region. Rather the moisture conditions were like those at present existing in the eastern part of the Great Plains, where the mesophytes are restricted to the stream borders along the valleys because the soil there is moist. Such at least is a reasonable conjecture. The cause of the greater aridity in Eocene times than at present is not known. Presumably a mountain range to the west may have cut off the moisture-bearing winds, thus reducing the amount of rainfall, though there is no direct evidence for supposing that such a range existed.

Concerning the temperature, the presence of such tropical or subtropical forms as *Smilax*, *Sterculea*, and *Liquidambar* suggests that the climate was warmer than that in the region today. The dominance of such temperate types as *Quercus*, *Acer*, *Ulmus*, and others puts the evidence in favor of a climate which was cooling, with the resultant invasion of the tropical flora by these temperate species. Apparently the climate, while somewhat warmer, was approaching the temperature conditions of the region today.

The flora of the Eagle Creek formation gives valuable suggestions as to the length of time involved in the epoch. From a purely physical standpoint, the great thicknesses of ash, tuff, and conglomerate might have been piled up in a comparatively short time, perhaps measured in scores of years rather than in units of a larger denomination. Turning, however, to the evidence of the plants, it may readily be shown that the time required is much greater. The number of years necessary for the development of a

climax forest of a mesophytic sort is estimated to be from one to two hundred years. This is on the basis of there being no soil at the outset, and of its development through the agencies of plants and weathering. It also assumes a soil favorable for the reception of plants. In the case of the soil furnished by the Eagle Creek rocks, there was a distinct time advantage due to the fact that they were not consolidated and therefore offered an immediate foothold for rooted plants. On the other hand the chemical composition of this sediment was probably quite unsuitable for the growth of most higher plants, certainly for the growth of mesophytes. The latter require a humus content which was entirely lacking in the original volcanic materials. Further, due to its basic composition, this may be supposed to have been quite unfavorable for the development of such seedlings as germinated in it. Experimental evidence has shown that of seeds planted in pulverized Eagle Creek rock from several localities, only those of oaks (xerophytes) developed successfully. The experiments were not satisfactorily completed, and it is not known whether the oak seedlings would have continued to develop in this soil. Observational evidence from regions recently covered by volcanic ash indicate that a number of years may elapse before the return of the higher plants. It is not unreasonable therefore to assume that the full one to two hundred years would have been required for the development of a climax mesophytic forest on the volcanic débris-strewn surface during Eagle Creek times.

While it is not possible to correlate the various horizons which contain plant remains in widely separated parts of the area, due to their limited horizontal extent, it is possible to determine, on the basis of relative elevation, that there are at least ten distinct horizons represented. Each of these contains leaves of the climax forest which, as we have seen, would require from one to two centuries for its development. The total length of time involved in the growth of the ten plant horizons may thus be placed at from one to two thousand years. And when it is realized that there must be numerous other plant-bearing horizons which have not been uncovered, the length of the epoch as inferred from plant growth may be greatly extended.

CONCLUSION

Plants may, then, with a degree of caution, be used, not only to show the character of past climate, but they may also be called upon to indicate the length of time involved in a given epoch, and the general character of the topography.

In the case of the Eagle Creek flora the climate appears to have been somewhat warmer and drier than at present. The length of the epoch is to be placed at thousands rather than at scores of years. The evidence of the dominant species of plants points to the probable existence of a twofold habitat, one xerophytic and the other mesophytic. An upland cut by valley-like depressions furnishes the conditions which are thus required by the plants and at the same time fits in equally well with the strictly geological characteristics of the Eagle Creek formation.